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FINAL REPORT FOR RESEARCH AGREEMENT
#INT-96087-RJVA
"Durability of Ponderosa Pine Snags in Relation to Fire History"
UNIVERSITY OF MONTANA
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Assessing longevity of ponderosa pine (*Pinus ponderosa*) snags in relation to age and pitch content

Completion Report for
INT-96087-RJVA

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ABSTRACT

Little is known about what factors contribute to the persistence of snags, a key factor of wildlife habitat in western forests. For this study, I investigated the relationships between tree age, pitch content, and outer wood density of ponderosa pine (*Pinus ponderosa*) trees and their longevity as snags. Longevity was classified by whether the snag was standing or had broken off below 10 feet (3 m), after 4 or 10 years. Snags, both standing and ones that had broken off, were sampled to determine their age, outer wood density, and pitch content. I predicted that older snags and snags with greater pitch content would be more durable. Pitch content was not found to be higher in standing snags versus broken ones, but age was found to be significantly different. Snags standing 10 years after mortality by a wildfire event averaged 228±25 years at one site and 273±19 at another site, while those broken averaged 154±24 years and 182±23, respectively. This study was exploratory in nature and further study is needed to develop more expeditious methodologies and to better understand factors that relate to snag longevity. This information will help land managers in making decisions regarding snag habitat for wildlife.

INTRODUCTION

Wildife habitat is an importat resource on National Forest lands. More attention is now being payed to nongame species habitat yet little information is available on habitat needs for many nongame species. Snags are an important component of forest structure and function (Harmon and others 1986). In the Blue Mountains of Oregon and Washington, for example, 39 bird species and 23 mammal species were found to use snags to roost, nest, and/or feed (Thomas and others 1979). Snags are centers for biodiversity since they provide habitat for forest insects and diseases, insectivorous birds, cavity nesters and other animals (Patton 1988).

The importance of insectivorous birds on controlling insect epidemics has been give wide attention for some time (Bruns 1960, Franz 1961, Herberg 1965). Much of the early work in Europe revealed that insectivorous birds do not single-handedly control insect outbreaks, but it was suggested that they may play an important role in helping to prevent outbreaks (Beebe 1974, DeGraaf 1977). In order to maintain high levels of biodiversity and to provide for a natural check on insect populations, large populations of various species of insectivorous birds are needed in our forests. Many species of insectivorous birds are dependent on snags for nesting and foraging sites. A lack of suitable snags is a major limiting factor for some bird species (Bruns 1960, Haapanen 1965, Balda 1975).

The many bird species that utilize snags have various structural requirements such as species, minimum diameter, minimum snag height, and state and type of decay of the snag (Thomas and others 1979, Neitro and others 1985). Since the various bird species require an array of different snag attributes (size, state of decay, etc.) to meet their habitat needs, managers generally use a 'coarse scale' approach to snag management. They try to provide snag habitat for birds requiring the largest diameter and greatest density of snags (Conner 1979, Evans and Conner 1979, Neitro and others 1985) and assume that needs of other birds will be met. Snag management guidelines vary by National Forest in western Montana, but generally they specify preferred species (ponderosa pine and western larch, *Larix occidentalis*) and call for trees ≥20" (50.8 cm) in diameter showing signs of defect or decay (R. Hickle 1996, personal

communication; M. Hillis 1996, personal communication; J. Ormiston 1996, personal communication; B. Summerfield 1996, personal communication).

Conclusions drawn from previous studies on various tree species in various areas have indicated that larger snags tend to remain standing longer (Dahms 1949, Keen 1955, Cline 1977, Lyon 1977, Conner 1979, Evans and Conner 1979, VanSickle and Benson, 1978) and that they can be used by more bird species (Conner 1979, Evans and Conner 1979, Neitro and others 1985).

Ponderosa pine is one of the main snag species used by birds in western Montana (McClelland and others 1979). Historically, ponderosa pine forests underwent frequent non-catastrophic fires that kept the stands more open with larger pines (Arno 1980, Arno 1988, Wickman and Swetnam 1996). There is anecdotal evidence that young ponderosa pine trees fall quickly once they become snags, whereas old-growth ponderosa pine snags remain standing for a much longer time (Stephen F. Arno, personal communication). It is thought that perhaps historical fire regimes may have caused pitching of the trees, leading to more stout boles. With this in mind, this study was initiated by the USFS Intermountain Research Station (now the Rocky Mountain Research Station) to assess the relationship between ponderosa pine trees' fire history as live trees and their longevity as snags.

OBJECTIVES

The overall purpose of this study was to try and gain a better understanding of factors affecting snag longevity in order for land managers to make better management decisions concerning wildlife habitat. In particular, I was interested in the effects of non-lethal, low-intensity fires on longevity of ponderosa pine snags. The process of resinosis that a coniferous tree undergoes when it is injured (Raffa and Berryman 1982, Owen and others 1987) is predicted to result in pitching of the bole, leading to a stronger, more persistent snag (Harrington 1996). Such resinosis is thought to happen when pine trees are wounded by the low intensities of naturally-occurring historical fires in ponderosa pine forests and those lit currently by forest managers.

The main objective, then, was to characterize the durability and structure of ponderosa pine snags over time for wildlife habitat within each of three age classes as follows:

1. Old growth pines -- trees >250 years old (those having been exposed to frequent fires in their lifetimes).
2. Intermediate-aged pines -- trees approximately 100-250 years old (those having been exposed to fire as young trees).
3. Bull pines -- those <100 years old (those having never survived low-intensity fires).

METHODS

STUDY SITES

Potential sites were identified according to stand history data obtained from the U.S. Forest Service and the Flathead Indian Reservation, Department of Forestry. The criteria to

select sites were similar habitat types (Pfister and others 1977), fire ecology groups (Fischer and Bradley 1987), aspect, year of stand-replacing fire event, no salvage logging following the fire, and the presence of numerous large-diameter [>15" (38.1 cm)] ponderosa pine snags to sample. Dissimilar site conditions, a lack of sufficient numbers of large snags, and salvage logging following fires greatly limited available study sites around western Montana and Idaho.

Due to obvious time constraints, I could not follow individual snags through time so I sampled snags created in two fire event years--1988 and 1994. By selecting snags created in these fire events, I could assess longevity over time. The two sites that burned in 1988 were Petty Creek 1 and 2, located on the Lolo National Forest about 30 miles west of Missoula, Montana. The two sites that burned in 1994 were Magruder, located in the Selway-Bitterroot Wilderness in central Idaho, and Nirada, located north of Polson, Montana on the Flathead Indian Reservation. All the sites had some trees with old fire scars visible indicating that the sites had undergone non-lethal underburns historically.

The fire that burned the Petty Creek area was a human-caused fire in July 1988 and was essentially a stand-replacing burn. Petty Creek 1 was owned by a private timber company prior to the burn, but has subsequently been acquired by the U.S. Forest Service. Because of this recent change in ownership, no stand history could be obtained; however, there was no evidence of logging prior to or following the fire. Petty Creek 2, located about one air-mile west of Petty Creek 1, is owned by the U.S. Forest Service and was not harvested prior to or following the fire.

Magruder, being located in a wilderness area, was not affected by logging prior to or following the 1994 fire. It appeared that the fire at Magruder was more patchy and less intense than the one at Petty Creek, resulting in more trees surviving. I would classify this as a mixed-severity burn.

Nirada is located on the Flathead Indian Reservation and there was no evidence of logging either prior to or following the 1994 burn. Like Magruder, it seemed the fire at Nirada was less intense than at Petty Creek, leaving more surviving trees. There was one Douglas-fir (*Pseudotsuga menziesii*) near the road with old fire scars on it. The tree had been cut and removed by firewood gatherers following the fire so I was able to take a cross-section from the stump. The tree originated in 1861 and had a definate fire scar around 1889 with probable fire scars from 1898 and 1912. The mean fire interval for the period before 1912 was17 years, with no evidence of a fire since that time. I think it is safe to say that this area definately experienced frequent, low-intensity fires prior to the beginning of this century.

Table 1 shows a summary of the site characteristics of the four sites sampled, including aspect, slope, elevation, habitat type (Pfister and others 1977), fire ecology group (Fischer and Bradley 1987), the year the stands burned, and the number of snags sampled, as well as the number broken, by age class.

Table 1. Aspect, slope, elevation, habitat type, fire ecology group, the year the stand burned, number of snags by age class, and number of broken snags by age class for each of the four study sites.

Site	Aspect	Slope	Elevevation (feet / meters)	Habitat type[1]	Fire group[2]	Year burned	# snags by age class (# broken)		
							Bull	Intermediate	Old-growth
PC1	W	51%	4000 / 1219	PSME/CARU-PIPO	4	1988	4 (3)	20 (11)	7 (2)
PC2	S-SW	42%	4200 / 1280	PSME/FESC	4	1988	1 (1)	11 (6)	10 (2)
Nirada	W	33%	4700 / 1433	PSME/CARU-PIPO	4	1994	1 (0)	20 (1)	2 (0)
Magruder	W-NW	63%	4100 / 1250	PSME/SYAL-CARU	6	1994	7 (0)	10 (0)	10 (0)

[1]Pfister and others (1977)
[2]Fischer and Bradley (1987)

The habitat types listed in table 1 did not necessarily coincide with those attained from records of examination prior to the fires. At all sites except Nirada, habitat typing in the field was difficult due to the incredible amount of knapweed (*Centaurea maculosa*) at the sites.

FIELD

Initially, I intended on getting an age for each tree at each site and then sub-sampling in order to get a good representation of each age class for both standing and broken snags. I quickly found that this was not realistic in terms of time and effectiveness. Generally, there was a lack of bull pines and it became apparent that there was not a good representation across age classes for the standing and broken trees. So, at each location, every snag that was available was sampled. A few snags could not be sampled due to safety concerns, I didn't have a long enough bore, I thought the snag died because of factors other than as a direct result of the fire (e.g., insect attack following the fire), or the bole of the tree had burned through and the sampling area was missing from the tree.

At each snag, site characteristics such as habitat type, aspect, slope, and location via global positioning system (GPS) were recorded. Tree data recorded included diameter at breast height (dbh), whether the snag was broken off below 10' (3 m), and height of the snag. I also noted feeding or nesting cavities of birds, fire scars, and presence of rot in the bole of the tree (Appendix I).

At least one core was taken to determine the age of the tree. If necessary, boring was repeated until an acceptable core was obtained. These cores were taken as close to ground-line as possible and were glued into grooved core boards and marked according to snag number and height it was taken for laboratory analysis. Cores were also taken to assess fire scar dates, when possible.

Wood density

Three core samples from the outer 10 cm of the snag were taken for wood density measures. The azimuthal locations on the tree were determined by using a random number generator with the number being the azimuth from the center of the tree. Cores were taken at

approximately 2.5 feet (~7.5 dm) from ground line so that the density measure was taken at the same general height as the cores for pitch. The increment borer was marked at 10 cm and inserted into the tree to that point, giving consistent sampling volume for density calculations. Each of the three density cores were placed in individual plastic zip-locked sandwich bags, which were sealed and marked.

Pitch content

Several increment cores were taken at approximately three feet (9 dm) from ground-line on each side of the tree to be used for the pitch analysis. All the cores from a given tree were placed in one plastic zip-locked sandwich bag, which was sealed and labeled. The number of cores taken from each snag was determined by estimating when enough sample by weight (~10 g) had been gathered for the chemical analysis. For consistency, an even number of cores was taken from each tree, with the same number taken from each side. The number of cores taken per tree was usually four, six, or eight. It took two people about 6 weeks to complete field sampling.

LABORATORY

Age data

The cores that had been mounted in the field were sanded down using an orbital sander with sandpaper grit up to 120 grains. Sanding by hand was done on fragile cores. Tree rings were counted under a dissecting scope or with a hand lens. If the pith of the tree was not intersected, a set of concentric circles was laid over the core to determine approximately how many rings were missed (Ghent 1955). For instance, if there were 2 rings per mm and it was estimated to be 3 mm to the pith, the correction added would be 6 years. Also added into the count was an adjustment for the height at which the core was taken (Arno and others 1985, Fiedler 1984). The total age of the tree was arrived at by the following computation:

A + P + H = Total age of tree
where:
A = Actual count,
P = Estimated years to pith, and
H = Estimated years to height of core extraction.

Additional corrections were added to some cores that had a good deal of rot. First, I assigned each of the cores a rating for quality--either good, minimal rot, or rot. To the 'good' cores I added no years; to the cores with minimal rot I added 30 years; and to the cores with rot, I added 80 years. I arrived at these corrections by estimating how much of the core was missing and by looking at other cores from the sites to determine the average number of years I lost to rot. I feel that these additions added to the accuracy of the ages, yet were still conservative. The trees were then assigned to an age class. Bull pine are those <100 years old, intermediate pine are those 100-250 years old, and old-growth pine are those >250 years old. Figures 1a-d show the distribution by age class before and after the corrections for rot were added.

Wood density

The zip-locked bags containing the density cores were weighed and then placed open in a 50°C drying oven for 24 hours. It was then weighed again to determine the dry mass of the sample. Since the same brand of zip-locked sandwich bags was used for all samples, and many samples were little more than dust, the weight of the sandwich bags was not subtracted from the weights. The following equations were used:

Volume of core sample = $\pi r^2 h = \pi$ (0.25 cm)^2 x 10 cm = 1.96 cm^3

Density = Dry weight (grams) / 1.96 cm^3

Chemical analysis for pitch content

The increment core samples collected were broken into small pieces and then ground in a small Wiley© mill. The ground matter was sifted and the material that could pass through a number 40 mesh screen, but be retained by a number 60 mesh screen was set aside. The bits that were still too large were then re-ground and the process was repeated until all the matter was ground. The size requirement of the wood is that posed by the chemical analysis standards that I followed (ASTM 1984, TAPPI 1988).

The standard testing methods (ASTM 1984) call for analyzing and drying two separate wood samples. Since I had a limited amount of material to work with, I lowered the drying temperature, increased the drying time, and used the same sample for both moisture determination and pitch content analysis. Approximately 2 grams of ground wood was placed in a tared Alundum thimble, which was then placed in a stoppered glass weighing bottle. The whole thing was weighed three times and placed (unstoppered) in a drying over at 50°C for a 24-hour period. The stopper was placed on the weighing bottle and it was placed in a desiccator to be cooled. Three weighings were then taken to determine dry weight of the sample. Moisture content, in % moisture of dry weight, was determined using the average of the three wet measures and the average of the three dry weights.

The dried and weighed sample was then placed in the Soxhlet extraction apparatus (ASK GARON) with Dichloromethane (also known as Methylene chloride or DCM) in the flask. The Soxhlet set-ups were located under a fume hood due to the potentially toxic effects of DCM. The sample was allowed to be extracted for a period of two hours with at least 6 siphonings per hour (ASTM 1984, TAPPI 1988). After the run was completed, the DCM solution with the extractives was transferred to a tared 100 ml beaker. DCM was evaporated until only 20-25 ml was remaining, which was placed in an oven at 105°C for a 1-hour period. The beakers were cooled in the desiccator and then weighed again to determine gain. The pitch content is reported as % of the dry weight of the sample, before extraction.

The methods (ASTM 1984, TAPPI 1988) call for the extraction time to be five hours, but after several test runs in a preliminary study, it was determined that there was no difference in extracted amount after two hours. Two chemical analysis runs were made for each snag sample in order to get an idea of the reliability of the test and the variability of the pitch content within each ground sample.

With 206 analyses to run (103 snags x 2 runs each), this was by far the most time-consuming portion of this study. On average, less than one snag sample was ground in the Wiley© mill per day. I had three Soxhlet extraction set-ups, so chemical analysis took at least 68 days to complete.

Statistical Analysis

I conducted goodness-of-fit tests using the G-test (Sokal and Rohl 1981) on the Petty Creek 1 data with the categorical variables 'Age class' versus 'Broken.' I was unable to conduct this test on the other three sites as there were zeros in one or more of the cells. I also ran the G-test on the combined data for Petty Creek 1 and 2.

Other data analysis was accomplished primarily on the computer using JMP IN® Software (SAS 1996). Two-sample t-test or analysis of variance tests were conducted for categorical measures versus continuous measures (e.g., 'Age class' versus 'dbh'), as well as Wilcoxon rank sum test or Kruskal-Wallis tests where there was concern that the data may not behave normally. If a significance was indicated and there were more than two categories, Tukey-Kramer HSD was run to determine where the significance was at. Regression analysis was conducted on continuous versus continuous measures (e.g., 'Average density' versus 'Average pitch'). All significance tests were conducted at $\alpha = 0.05$.

RESULTS

The distribution of the sample data behaved relatively normal for age, dbh, average pitch, and average wood density. Based on the assumption that the population data for these attributes is normally distributed, I accepted the parametric results with one exception. That one exception was because the nonparametric and parametric results differed in their outcome and practical significance was evident only with the nonparametric test results.

In order to report all possible relationships for longevity (standing versus broken), diameter distribution, age class, pitch content, and density for each site, I am presenting the data in separate tables with relationships shown. Also, I will show if and how those relationships change when the data from the two sites from each fire year are grouped together (tables 2-8).

A note of caution is needed regarding the wood density relationships. There were obvious differences in the wood densities for trees that had broken below 10' (3 m) versus those still standing, but the boles had been exposed to different weathering at the point where the cores were extracted. The differences in wood density could be a result of the breaking, not vice versa.

Table 2 shows the mean and standard error of the sample mean for each of the attributes (age, dbh, average pitch, and average density) at each location by age class and snag status (overall, standing, broken). Statistical differences are also indicated and will be discussed on a site by site basis.

Table 2. Mean and standard error of the sample mean for age, dbh, average pitch, and average density at each site (Petty Creek 1, Petty Creek 2, Nirada, and Magruder) for each age class (bull pine, intermediate pine, and old-growth pine) according to snag condition (overall, standing, or broken). Statistically significant differences are identified by bold type and matching letters following the values.

		PC1			PC2			Nirada			Magruder		
		overall	standing	broken	overall	standing	broken	overall	standing	broken	overall	standing	broken
Bull pine	n=	4	1	3	1	0	1	1	1	0	7	7	0
	age (years)	83±5	74	85±6	63	--	63	66	66	--	93±1	93±1	--
	dbh (inches)	**15.3±0.6 (a)**	16.9	14.8±0.42	15	--	15	17.3	17.3	--	**18.1±0.6 (g, h)**	18.1±0.6	--
	ave.pitch (%)	6.78±1.36	7.82	6.44±1.86	16.16	--	16.16	4.80	4.80	--	8.23±2.07	8.23±2.07	--
	ave.density (g/cm^3)	1.68±0.10	1.9	1.61±0.1	1.63	--	1.63	1.92	1.92	--	1.84±0.02	1.84±0.02	--
Intermediate pine	n=	20	9	11	11	5	6	20	19	1	10	10	0
	age (years)	156±10	171±14	143±13	189±15	**221±11 (f)**	**163±21 (f)**	193±8	194±8	168	225±9	225±9	--
	dbh (inches)	**18.5±0.6 (b)**	18.7±1.1	18.3±0.8	22.3±1.1	24.3±1.7	20.6±0.9	20.6±0.8	20.7±0.8	18.4	**26.5±1.4 (g)**	26.5±1.4	--
	ave.pitch (%)	12.61±1.43	12.15±2.02	12.98±2.10	10.87±1.25	8.83±1.96	12.57±1.39	7.14±0.88	7.02±0.92	9.53	9.07±1.59	9.07±1.59	--
	ave.density (g/cm^3)	**1.63±0.03 (c)**	**1.71±0.05 (d)**	**1.57±0.03 (d)**	**1.56±0.02 (e)**	1.56±0.04	1.56±0.02	1.78±0.02	1.78±0.02	1.74	1.87±0.02	1.87±0.02	--
Old-growth pine	n=	7	5	2	10	8	2	2	2	0	10	10	0
	age (years)	349±28	361±38	317±16	305±11	306±12	299±36	341±38	341±38	--	320±18	320±18	--
	dbh (inches)	**22.9±1.4 (a, b)**	24.1±1.6	19.7±0.60	19.7±1.0	19.8±1.3	19.7±1.3	29.7±5.6	29.7±5.6	--	**28.5±1.7 (h)**	28.5±1.7	--
	ave.pitch (%)	13.48±2.31	13.61±2.12	13.15±8.20	7.56±1.23	7.11±1.24	9.33±4.61	6.56±2.49	6.56±2.49	--	5.10±0.68	5.10±0.68	--
	ave.density (g/cm^3)	**1.85±0.03 (c)**	1.86±0.04	1.84±0.04	**1.73±0.04 (e)**	1.73±0.05	1.74±0.14	1.92±0.04	1.92±0.04	--	1.84±0.03	1.84±0.03	--

a: t= -3.021, P=0.004
b: t= -3.258, P=0.003
c: t= -4.017, P<0.001
d: t= 2.471, P=0.024
e: t= -3.808, P=0.001
f: t= 2.366, P=0.042
g: t= -4.707, P<0.001
h: t= -5.061, P<0.001

Petty Creek 1 (tables 2,3)

The G-test for goodness-of-fit was conducted for PC1 which suggested that age class and longevity were not related (P>0.250).

Petty Creek 1 (PC1) data revealed there were significant relationships between snag longevity and age (P=0.042). The actual ages were used instead of the age classes for this test. It was found that the mean age of broken snags (n=16) was 154±24 years while the mean age of those still standing (n=15) was 228±25 years.

Without separating the data by age class, the snags that had broken were significantly less dense than those standing with those standing having a mean density of 1.77±0.04 g/cm^3 and those broken averaging 1.61±0.04 g/cm^3 (P=0.004). After separating the data according to age classes, there were two more significant findings. There was a difference between average density of intermediate pines (1.63±0.03) and old-growth pines (1.85±0.03) (P=<0.001). There was also a significant difference between the standing and broken pines in the intermediate age class (P=0.024) with the standing being more dense (1.71±0.05) than the broken (1.57±0.03).

As would be expected, older trees were also larger in diameter. The ANOVA determined that there were significant differences (P<0.01) and Tukey-Kramer HSD indicated that only significant difference was that old-growth trees were larger (22.9±1.1") than both intermediate-aged and bull pines. Although the mean of the intermediate age class was about three inches greater than that of the bull pine class (18.5±0.7" versus 15.3±1.5"), it was not a significant difference.

The only other significant correlation found for PC1 was with age class versus average density (P=0.004). The old-growth trees were more dense (1.85±0.05 g/cm^3) than either the intermediate-aged trees (1.63±0.03 g/cm^3) or the bull pines (1.68±0.07 g/cm^3).

Table 3. Summary of correlation analyses for longevity, dbh, age class, average pitch, and average density for Petty Creek 1, n=31. Significant results are in bold.

	DBH	Age Class	Average Pitch	Average Density
Longevity	t-test t=2.030, P=0.052	**t-test** **t=2.126, P=0.042** **(actual ages used)**	t-test t=0.252, P=0.803	**t-test** **t=3.132, P=0.004**
DBH	---	**ANOVA** **F=9.517, P=0.0007**	t-test t=0.33, P=0.745	t-test t=1.15, P=0.261
Age Class	---	---	ANOVA F=1.790, P=0.186	**ANOVA** **F=6.959, P=0.004**
Average Pitch	---	---	---	t-test t= -0.76, P=0.455

Petty Creek 2 (tables 2, 4)

As with PC1, snags at Petty Creek 2 (PC2) that were broken off were significantly younger (P=0.005). Mean age of standing snags (n=13) was 273±19 years and mean age of broken ones (n=9) was 182±23 years. When separated into age classes, there was a significance

seen in age between standing and broken snags of the intermediate age class (P=0.042). Broken snags averaged 163±21 years while those remaining standing averaged 221±11 years.

The average pitch for all broken snags (12.25±1.30%) was significantly higher than that for standing snags (7.77±1.08%) (P=0.015). There was a significant negative relationship between dbh and average density (P=0.03). Consistent with PC1, old-growth trees were more dense (1.73±0.03 g/cm^3) than intermediate-aged pines (1.56±0.03 g/cm^3) (P=0.005).

Table 4. Summary of correlation analyses for longevity, dbh, age class, average pitch, and average density for Petty Creek 2, n=22. Significant results are in bold.

	DBH	Age Class	Average Pitch	Average Density
Longevity	t-test t=1.123, P=0.275	**t-test** **t=3.119, P=0.005** **(actual ages used)**	**t-test** **t= -2.649, P=0.015**	t-test t=1.080, P=0.293
DBH	---	ANOVA F=3.022, P=0.073	t-test t= -0.66, P=0.514	**t-test** **t= -2.34, P=0.03**
Age Class	---	---	ANOVA F=3.159, P=0.065	**ANOVA** **F=7.266, P=0.005**
Average Pitch	---	---	---	t-test t= -1.11, P=0.279

Nirada (tables 2, 5)

Since there was only one broken snag at Nirada, I was unable to study longevity there. There were no significant relationships found with the Nirada data.

Table 5. Summary of correlation analyses for between longevity, dbh, age class, average pitch, and average density for Nirada, n=23. Significant results are in bold.

	DBH	Age Class	Average Pitch	Average Density
Longevity (only one broken tree)	ANOVA F=0.419, P=0.525	ANOVA F=0.269, P=0.61	ANOVA F=0.465, P=0.503	ANOVA F=0.310, P=0.583
DBH	---	Kruskal-Wallis χ^2=3.945, P=0.139	t-test t=1.28, P=0.216	t-test t=1.43, P=0.166
Age Class	---	---	ANOVA F=0.185, P=0.833	ANOVA F=2.754, P=0.088
Average Pitch	---	---	---	t-test t= -0.49, P=0.631

Magruder (tables 2, 6)

Like Nirada, there was no capacity to analyze longevity at Magruder because there were no broken snags sampled at Magruder. The only significance found at Magruder was with age class versus dbh (P<0.001). Intermediate and old-growth pines were each significantly larger than bull pines. The mean diameter for old-growth pines was 28.5±1.4", for intermediate-aged pines it was 26.5±1.4," and for bull pines it was 18.1±1.6".

Table 6. Summary of correlation analyses for longevity, dbh, age class, average pitch, and average density for Magruder, n=27. Significant results are in bold.

	DBH	Age Class	Average Pitch	Average Density
Longevity (No broken trees)	---	---	---	---
DBH	---	**ANOVA F=12.962, P<0.001**	t-test t= -0.39, P=0.698	t-test t= -1.55, P=0.134
Age Class	---	---	ANOVA F=2.299, P=0.122	ANOVA F=0.636, P=0.538
Average Pitch	---	---	---	t-test t= -1.39, P=0.176

Combined sites

The distribution of the variables dbh, age, average pitch, and average density was relatively well-behaved for all sites. For PC1 and PC2, there was no significant differences seen in mean dbh, age, average pitch, or average density (figs. 2-5). For Magruder and Nirada, there was only one significant difference and that was in mean dbh (25.1±0.9" versus 21.3±1.0") (figs. 2-5). Based on these findings, I felt it was appropriate to pool the data from the 1988 sites together and that from the 1994 sites together to investigate the influences of larger sample sizes on the relationships.

1988 Sites (table 7)

The G-test for goodness-of-fit was conducted on the combined PC1 and PC2 data for age class versus longevity which indicated that age class and longevity were related (P<0.05).

For the other statistical measures on the commbined data from PC1 and PC2, five significant relationships were seen. The first, dbh versus longevity, was not detected in either individual site (P=0.019). Broken snags had a significantly smaller diameter than non-broken ones (18.5±0.7" versus 20.9±0.7").

As was seen in both individual sites, broken snags were significantly younger than non-broken snags (P<0.001) with a mean age of 164±17 years. The standing snags averaged 249±16 years old. One more significance was seen with regards to longevity; broken snags were significantly less dense (P=0.005) than standing snags (1.61±0.03 g/cm^3 versus 1.72±0.03 g/cm^3).

The diameter distribution for the three age classes showed successively larger means. The ANOVA showed significance with P=0.008, but the only significance was that the mean of bull pines was smaller than the mean for either intermediate pines or old-growth pines (according to the Tukey-Kramer HSD). Old-growth pines averaged 21.1±0.8", intermediate pines averaged 19.8±0.6", and bull pines were 15.3±0.8" in diameter.

The final test of significance was that old-growth trees were significantly more dense than the intermediate-aged trees (P<0.001 and Tukey-Kramer HSD). Average density for the bull pines was quite variable, leading to a mean of 1.67±0.06 g/cm^3 causing it to overlap both intermediate and old-growth. Intermediates averaged 1.61±0.02 g/cm^3, while old-growth trees averaged 1.78±0.03 g/cm^3.

Table 7. Summary of correlation analyses for longevity, dbh, age class, average pitch, and average density for 1988 sites combined, n=53. Significant results are in bold.

	DBH	Age Class	Average Pitch	Average Density
Longevity	**t-test t=2.433, P=0.019**	**t-test t=3.566, P<0.001 (actual ages used)**	t-test t= -1.115, P=0.27	**t-test t=2.943, P=0.005**
DBH	---	**ANOVA F=5.365, P=0.008**	t test t= -.041, P=0.681	t-test t= -0.50, P=0.621
Age Class	---	---	ANOVA F=1.922, P=0.312	**ANOVA F=10.472, P<0.001**
Average Pitch	---	---	---	t-test t= -0.93, P=0.355

1994 Sites (table 8)

Combining Magruder and Nirada did little to increase the number of relationships found to be significant. The one relationship found to be significant was age class versus dbh (P<0.001). In the combined sites, however, all age classes were significantly different than one another. The old-growth trees averaged 28.7±1.3," mean for the intermediate-aged trees was 22.6±0.8," and the average for the bull pines was 18.0±1.6".

Table 8. Summary of correlation analyses for longevity, dbh, age class, average pitch, and average density for 1994 sites combined, n=50. Significant results are in bold.

	DBH	Age Class	Average Pitch	Average Density
Longevity (Only one broken tree)	t-test t=0.887, P=0.38	t-test t=0.553, P=0.583 (actual ages used)	t-test t= -0.562, P=0.577	t-test t=0.950, P=0.347
DBH	---	**ANOVA F=14.641, P<0.001**	t-test t=0.39, P=0.702	t-test t=0.63, P=0.535
Age Class	---	---	ANOVA F=1.620, P=0.209	ANOVA F=1.183, P=0.315
Average Pitch	---	---	---	t-test t= -1.11, P=0.274

As one final summary of the results obtained from the individual sites or combined sites, table 9 presents the relationships and which sites had significant results among them.

Table 9. Summary table of which sites showed significant results in correlation analyses for longevity, dbh, age class, average pitch, and average density.

	DBH	Age Class	Average Pitch	Average Density
Longevity	1988	PC1, PC2, 1988	PC2	PC1, 1988
DBH	---	PC1, 1988, Magruder, 1994	---	PC2
Age Class	---	---	---	PC1, PC2, 1988
Average Pitch	---	---	---	---

Even though there will be no direct comparison between the different years, some interesting differences occurred. There was no difference between mean age of the 1994 sites (214±13 years) and 1988 sites (209±12 years) (fig. 6), but the snags making up the 1994 sites were significantly larger (fig. 7). The mean diameter of snags from the 1994 sites was 23.3±0.7" and the mean from 1988 sites was 19.8±0.7". This difference could be attributed to different site conditions and thus growing conditions, or it could be due to more bark remaining on the 1994 snags.

Average density was significantly higher for the 1994 sites (fig. 8). The mean was 1.83±0.17 g/cm^3 compared to 1.67±0.17 g/cm^3 for the 1988 sites. Counter to this, the average percent pitch was significantly higher for the snags from the 1988 sites (fig. 9). The mean was 11.04±0.68% compared to only 7.20±0.71% for the 1994 sites.

MANAGEMENT IMPLICATIONS

The predication that pitch would be higher in the old-growth trees was not born out by this data. I don't think the picture is clear, though. Since I combined sapwood and heartwood together for the chemical analysis this may have affected the outcome. Heartwood generally has more pitch in it (Conner and others 1980) and depending on the proportion of heartwood to sapwood, the overall % pitch will be affected. Also at play here is the density of the outer wood. With increasing rot in the outer sapwood area, the % pitch would presumably increase as the proportion of heartwood would be much greater. This could explain the general opposition of % pitch and density measure as seen at PC2, Magruder, and to some degree at Nirada. Future studies of this type should probably separate the heartwood from the sapwood in the field and conduct the chemical analysis on them separately. I am currently conducting further investigations into this matter.

Age, density, and durability have some interesting interactions for the 1988 sites. The old-growth trees are significantly more dense, and snags that have broken off are significantly younger and less dense than those still standing. I think this is where the most crucial management implications lie. According to the data I collected it appears that ponderosa pine snags in western Montana have a greater chance of remaining standing at least 10 years if the trees are >250 years old.

Generally, I think that wildife habitat managers have appropriate guidelines according to minimum diameter for ponderosa pine snags--both at PC1 and PC2 the overall mean diameter of broken snags was below 20" (50.8 cm)and for those standing was greater than 20" (50.8 cm). It might be a good idea to increase that minimum diameter by a few inches to be on the safe side. I think that age should be added to the management guidelines as a criterion as it appears that older trees stay standing longer once they die. Keep in mind, though, that the ponderosa pine trees that were >250 years old in 1988 lived through much different environmental forces than trees currently do. The primary difference in todays Douglas-fir/ponderosa pine forest is the lack of frequent, non-lethal underburns which helped to maintain more open sites. That fire regime helped to recycle nutrients and reduced competition stress to the remaining trees.

Further studies are needed in this topical area to provide more precise snag guidelines for managers, both in the Northern Rocky Mountains and elsewhere. Proposals to 'restore' the relatively rare old-growth forests through thinning and reintroduction of fire will need to carefully consider how these treatments may affect both standing and potential snags. This fact is underscored by this study, in particular, since the most persistent snags appear to be in the relatively rare old-growth snags.

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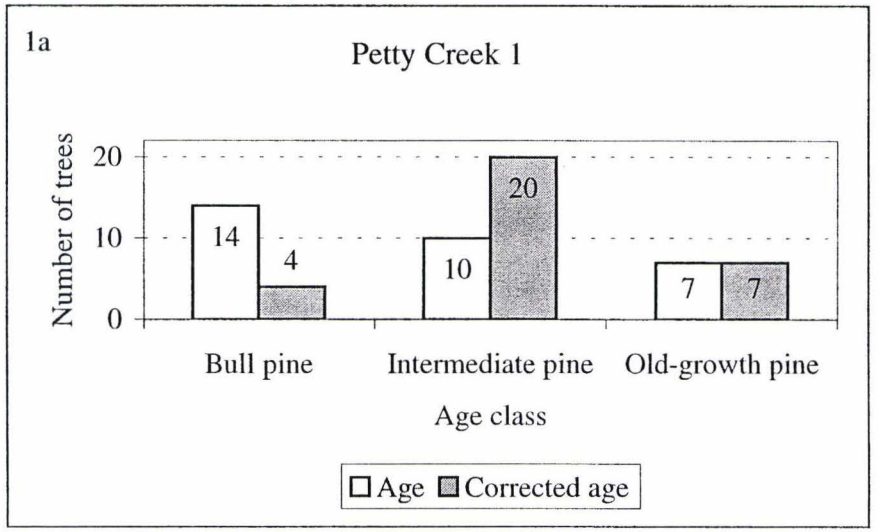
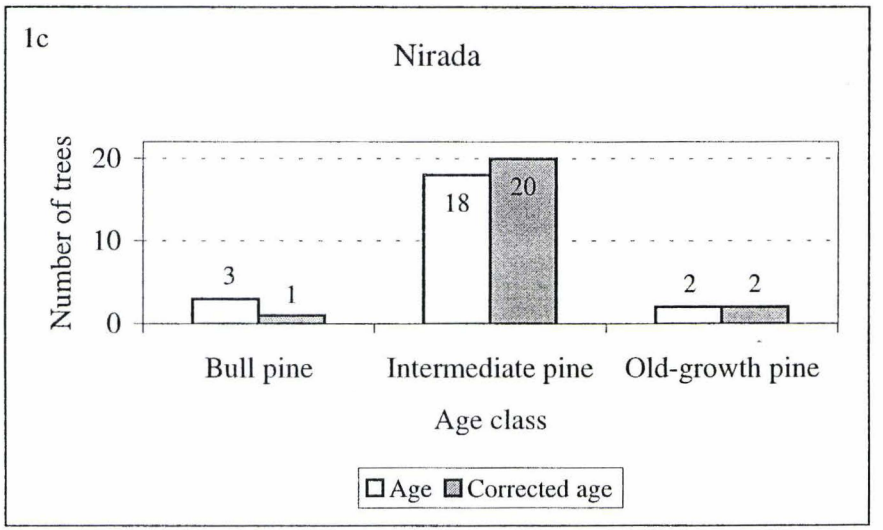
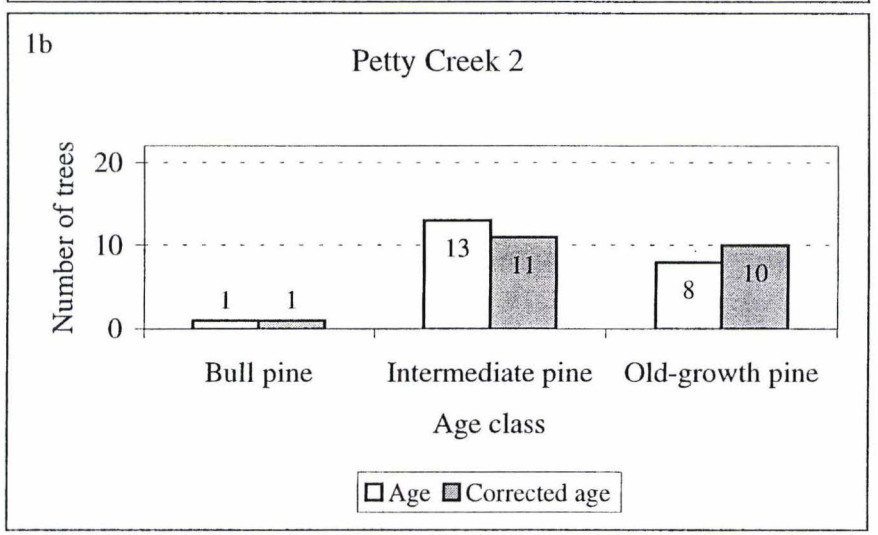
Figures 1a-1d. Age distributions for Petty Creek 1, Petty Creek 2, Nirada, and Magruder before and after corrections for rot were added.







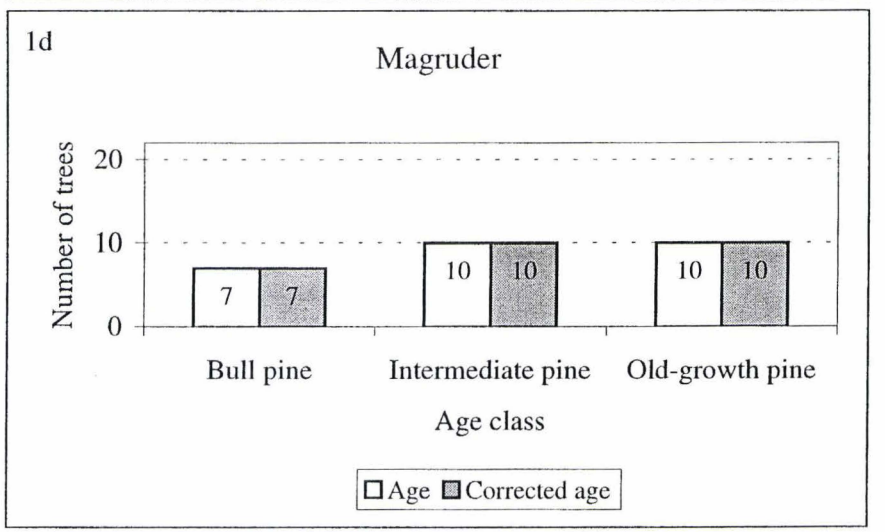


Figure 2. Mean diameters (inches) and standard errors of the means by site. Significantly different means have different letters.

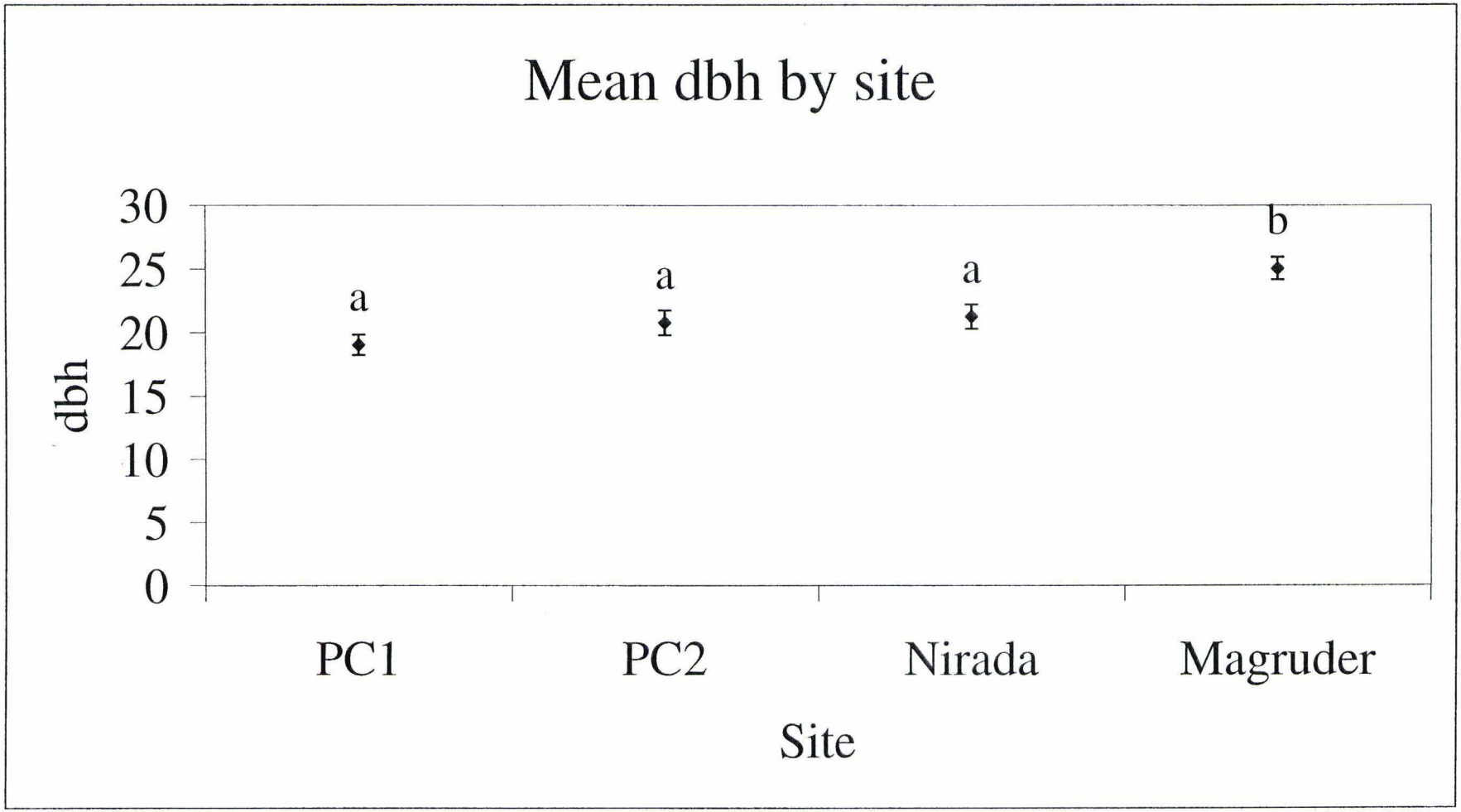


Figure 3. Mean ages (years) and standard errors of the means by site. Significantly different means have different letters.

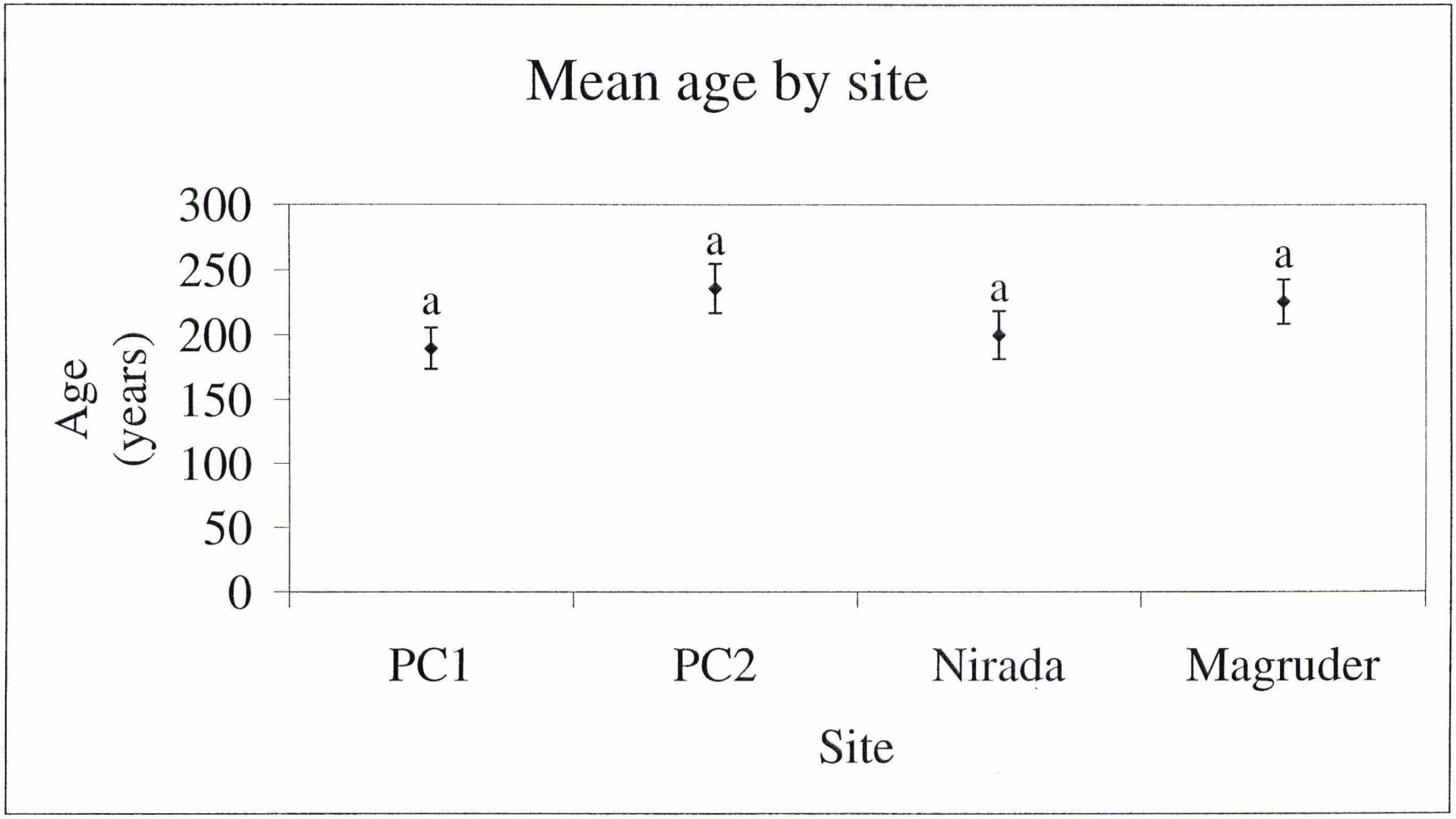


Figure 4. Mean average pitch (%) and standard errors of the means by site. Significantly different means have different letters.

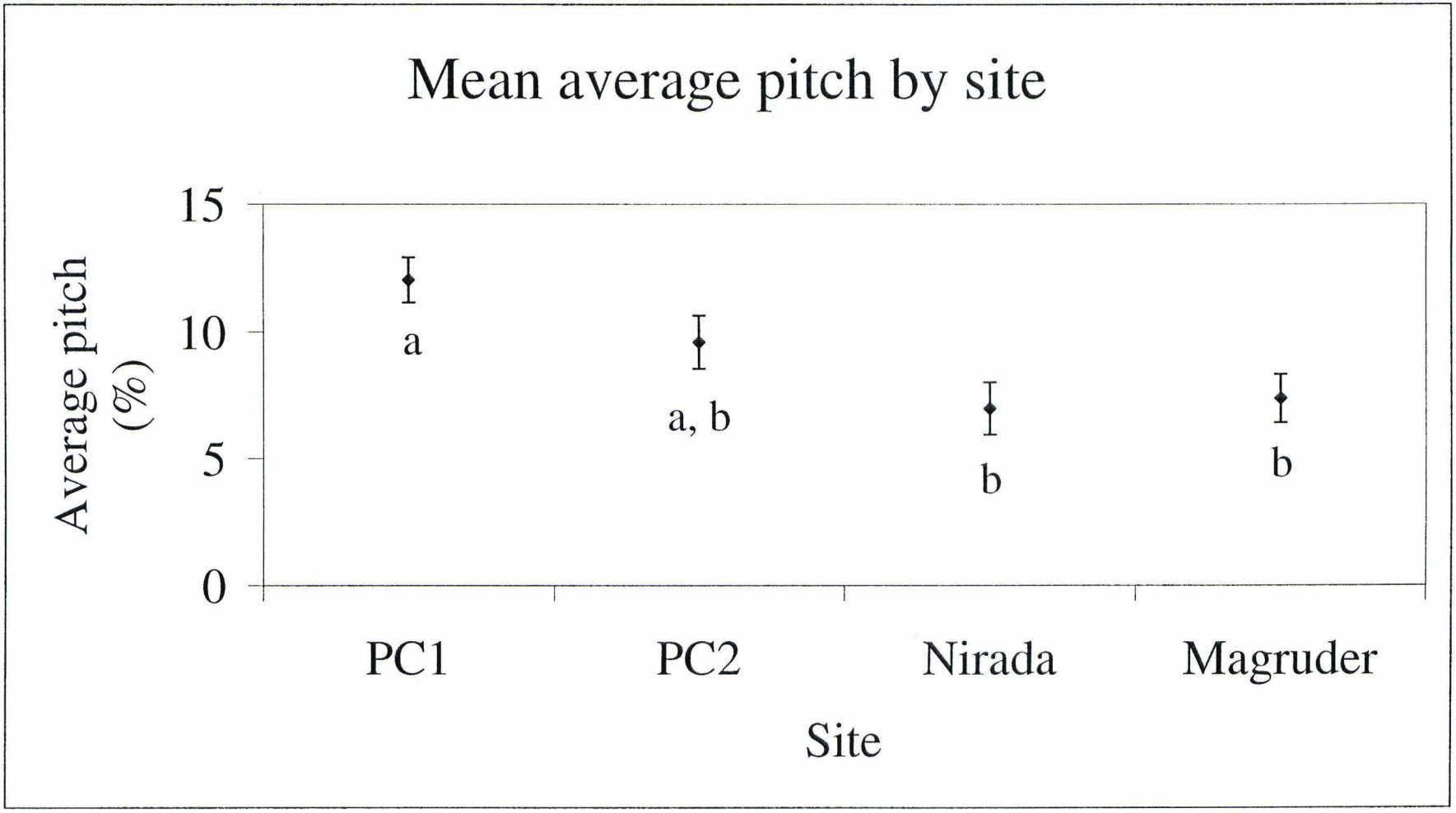


Figure 5. Mean average density (g/cm^3) and standard errors of the means by site. Significantly different means have different letters.

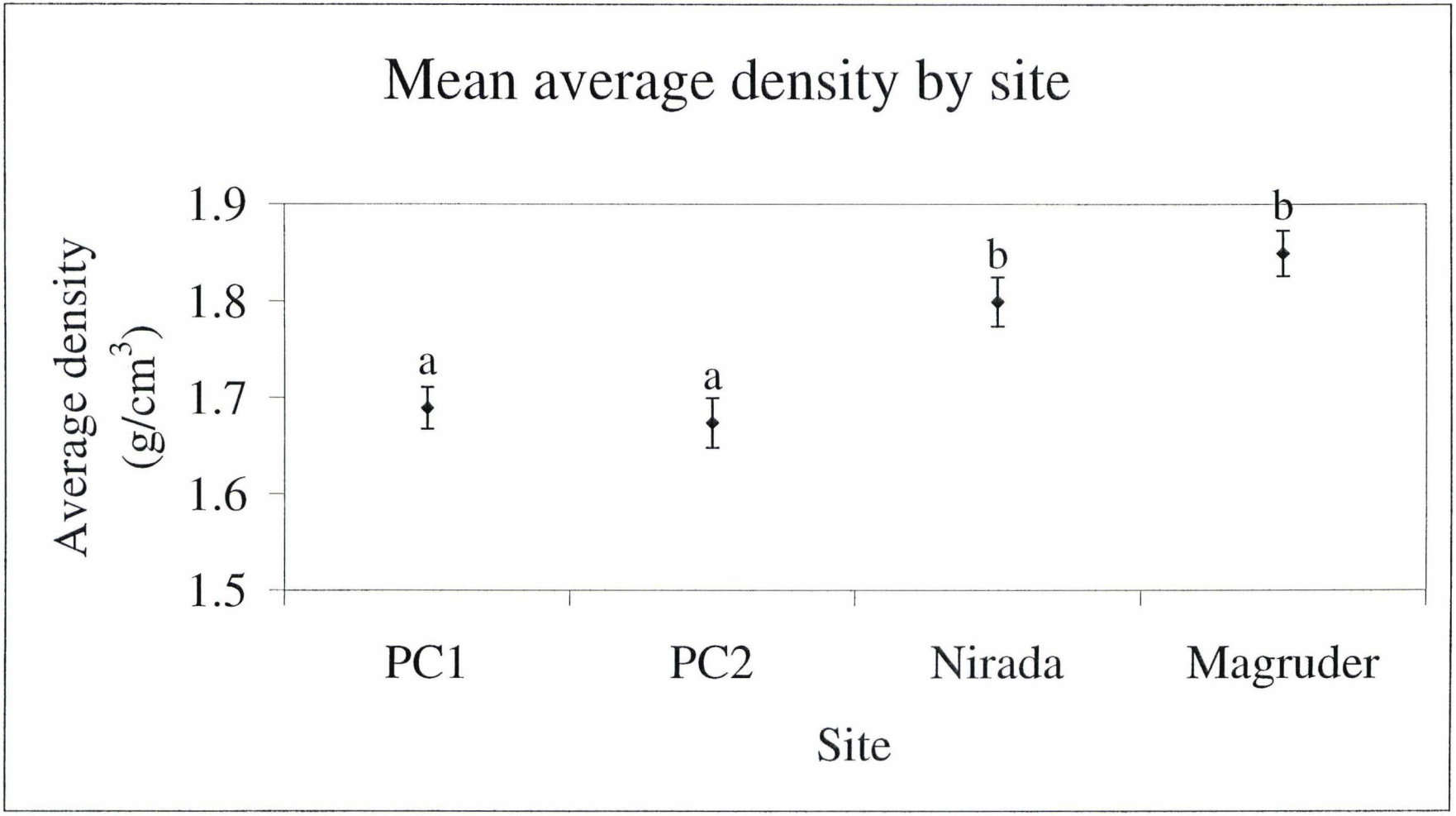


Figure 6. Mean age (years) and standard error of the mean by fire year. Statistically significant means are labeled with different letters.

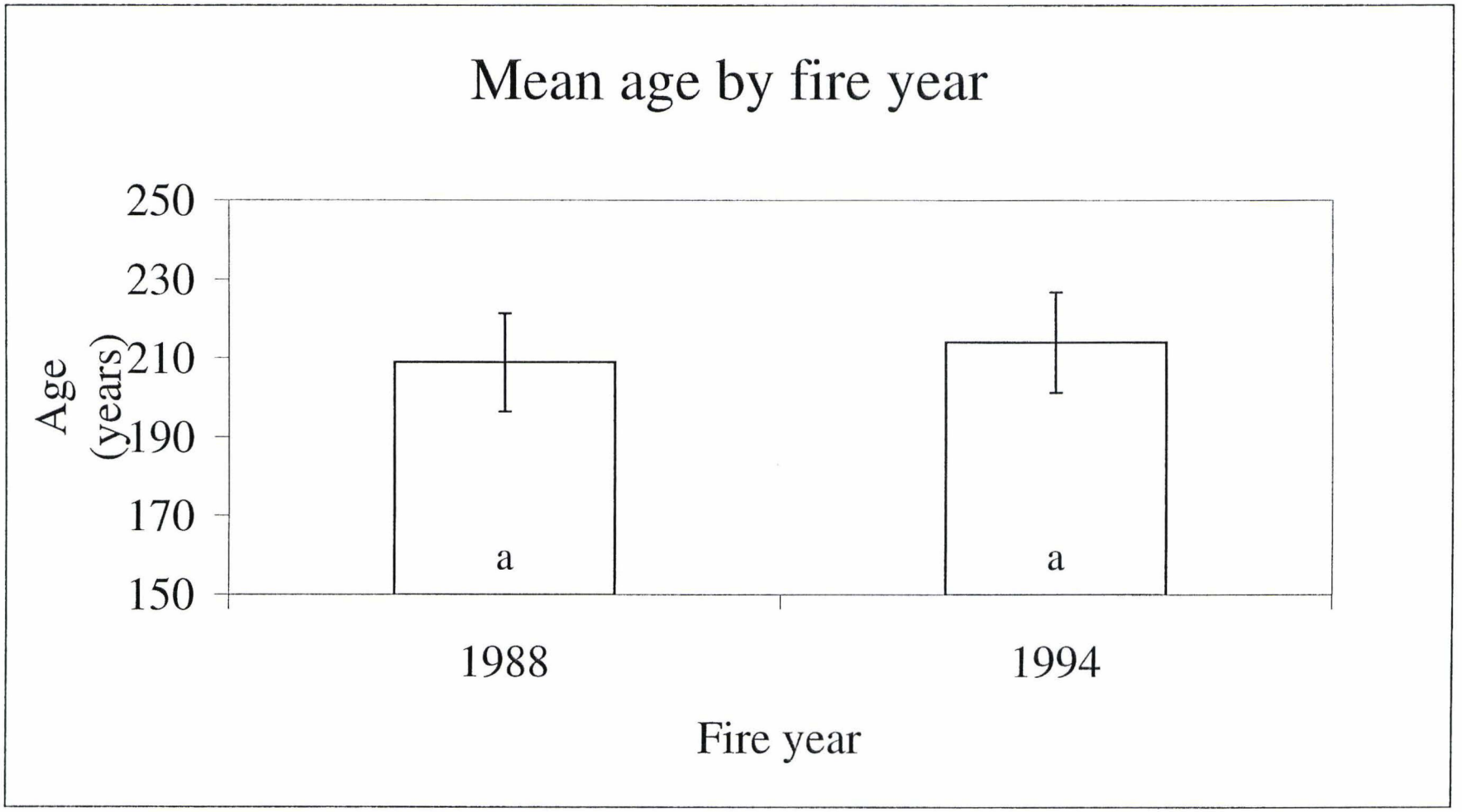


Figure 7. Mean diameter (inches) and standard error of the mean by fire year. Statistically significant means are labeled with different letters.

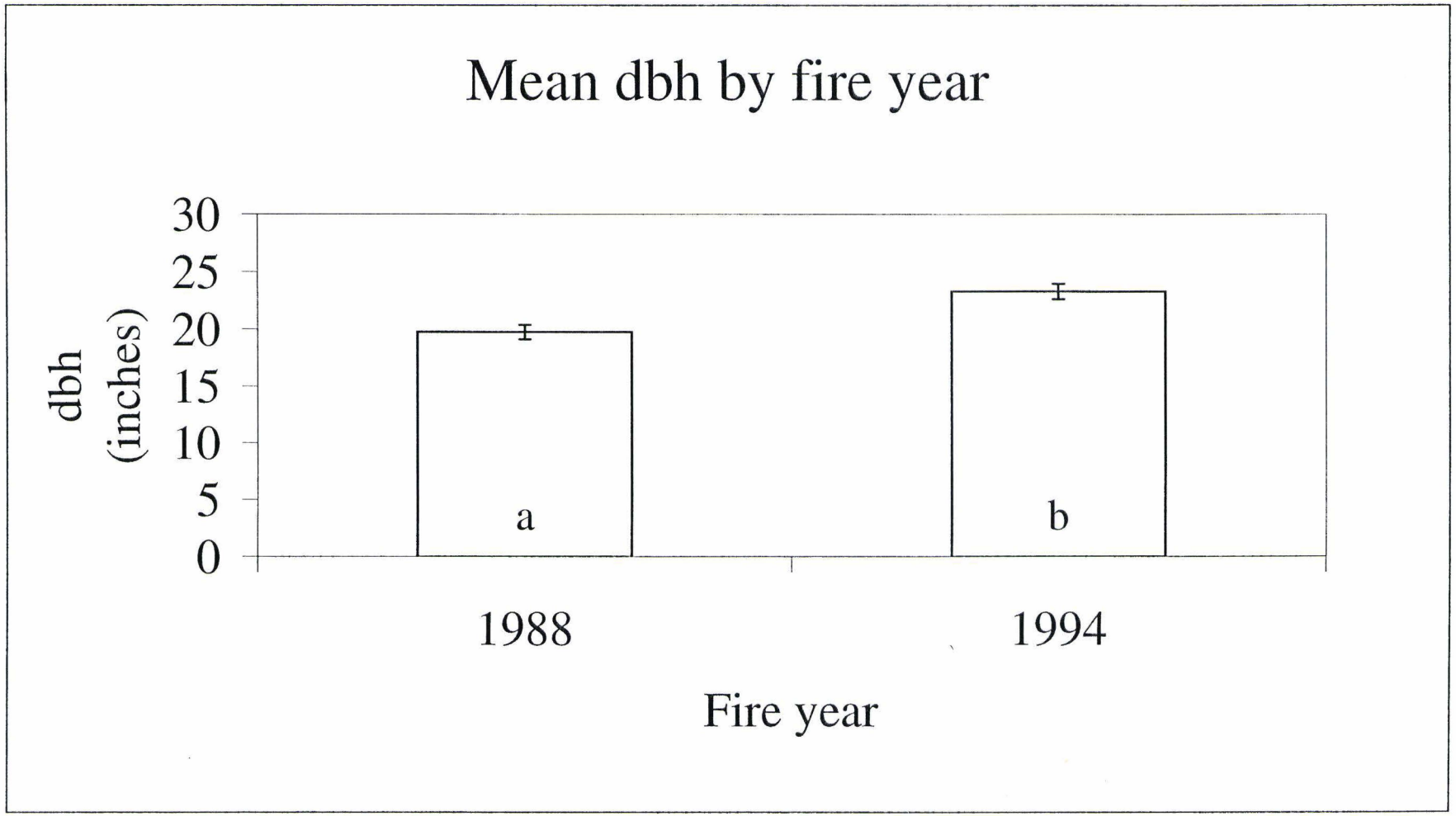


Figure 8. Mean average pitch (%) and standard error of the mean by fire year. Statistically significant means are labeled with different letters.

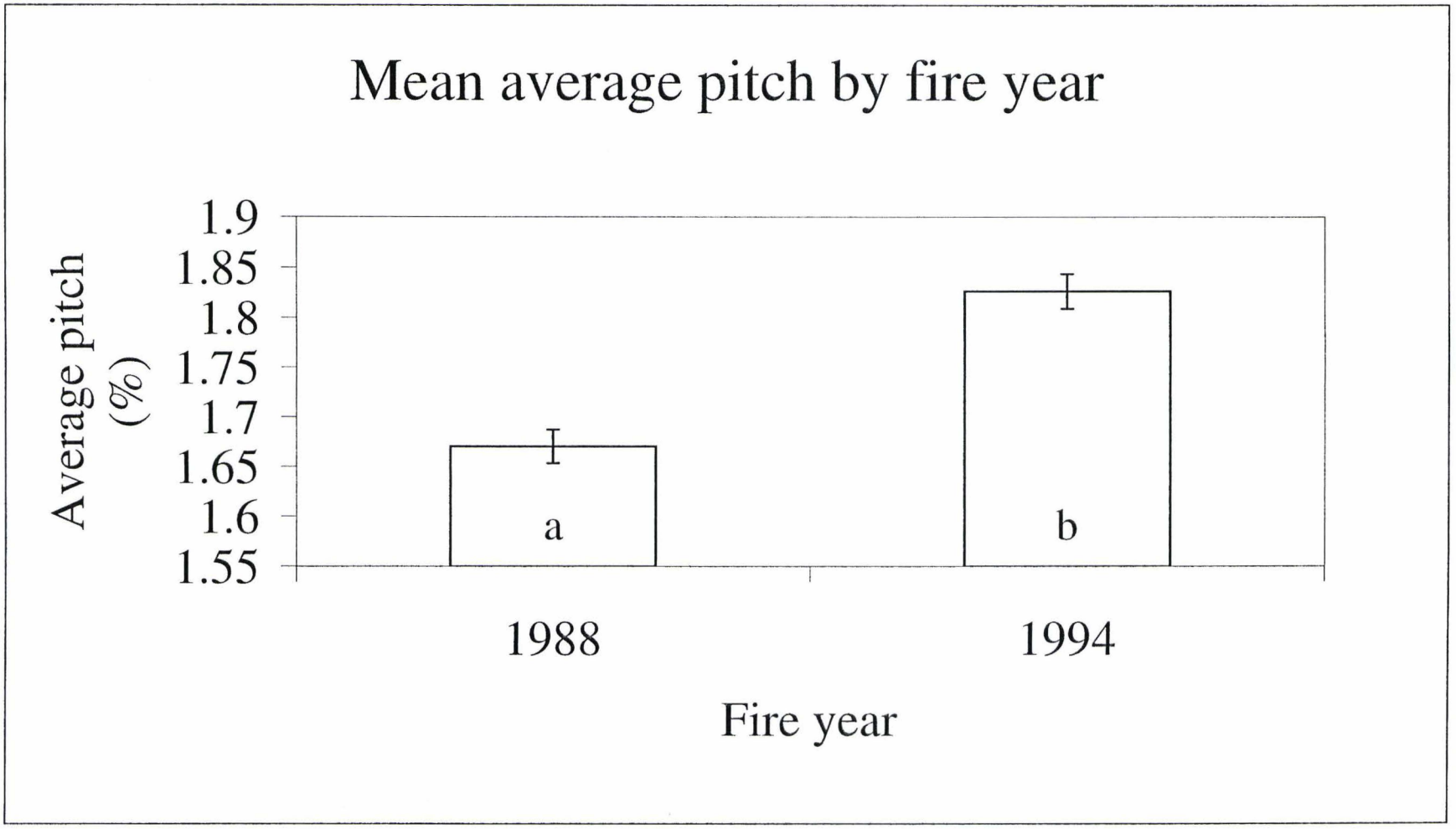
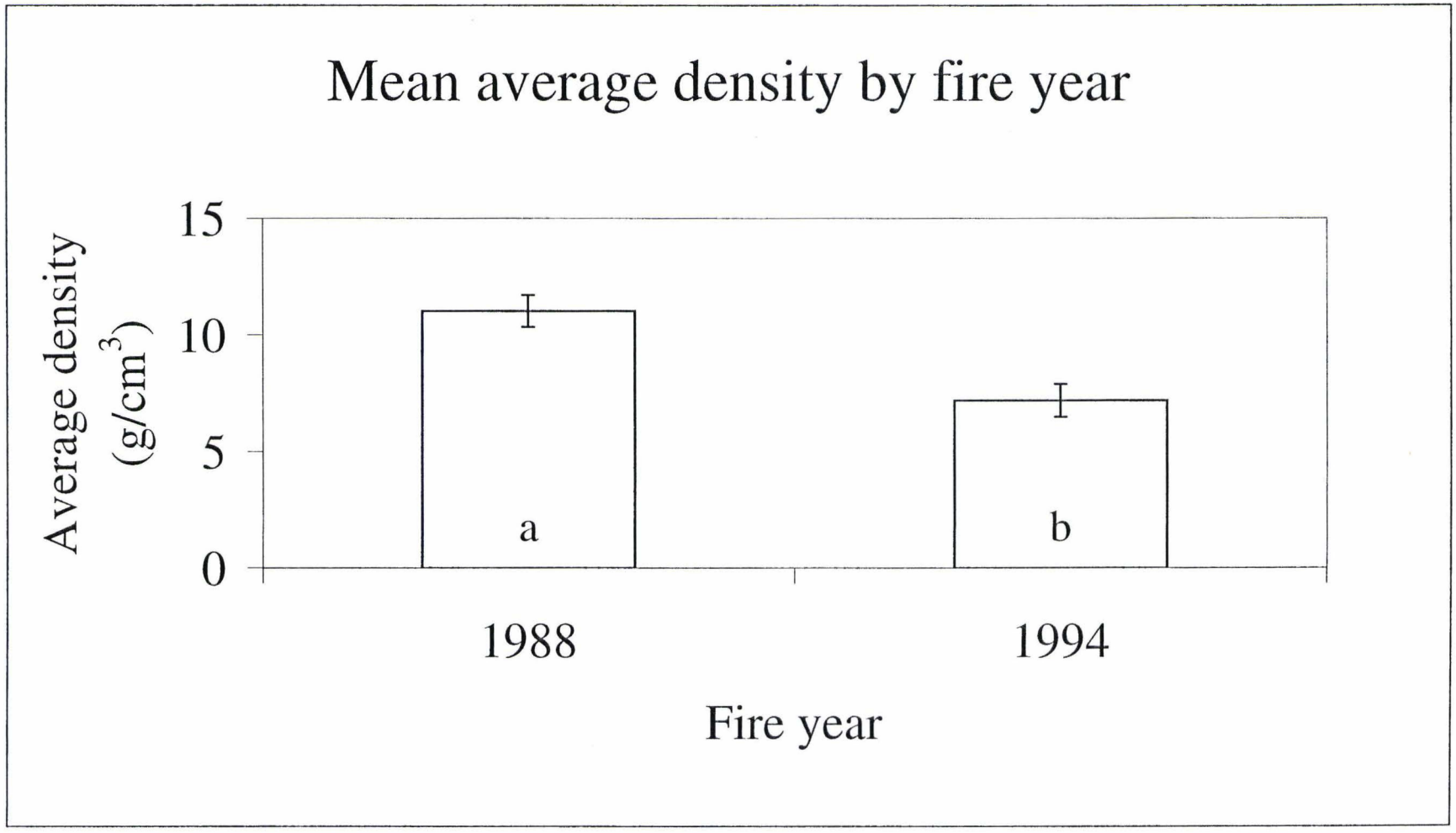


Figure 9. Mean average density (g/cm^3) and standard error of the mean by fire year. Statistically significant means are labeled with different letters.



APPENDIX I

Field form used for recording data at each snag sampled

Location_____ Date_____

Aspect_____° Slope_____% H.T._____

Tree#_____ Diameter_____" Diameter taken at _____'

Broken? __Y __N If standing, height of tree Decay class

Height of break_____' _____' _____

Height age core taken at _____' Side of tree age core taken from __U __D __L __R

Pitch cores taken at ~3' on sidehills (L&R)

Approximate age of tree _____ years

Rot present?_____ How much?_____" Where? OUTER INNER CENTER

Fire scars visible?____ #_____ Where on tree (U, D, L, R)?_____

Comments_____

_____

_____

_____

GPS File: Time: # Points:

Density cores:

Azimuth

_____

_____

_____